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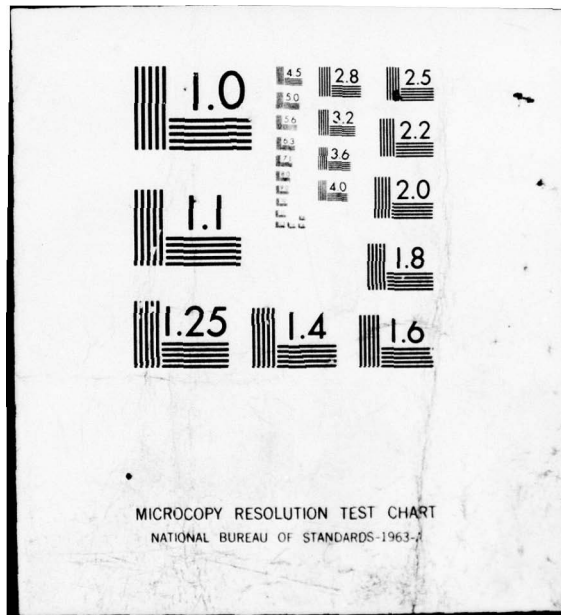
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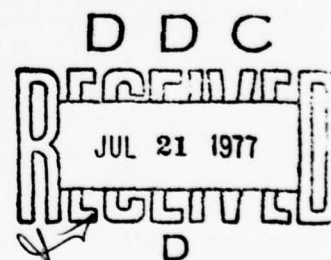


## PROGRAM MANAGEMENT COURSE INDIVIDUAL STUDY PROGRAM

APPLICATION OF PRODUCT IMPROVEMENTS  
TO THE M60A1 MAIN BATTLE TANK:  
A DECISION ANALYSIS

STUDY PROJECT REPORT  
PMC 76-1

Donald W. Derrah  
Major USA



FORT BELVOIR, VIRGINIA 22060

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STUDY TITLE: APPLICATION OF PRODUCT IMPROVEMENTS TO THE M60A1 MAIN BATTLE  
TANK: A DECISION ANALYSIS

## STUDY PROJECT GOALS:

1. To establish the program objectives.
2. To define feasible alternatives to meet objectives.
3. To analyze and compare courses of action.
4. To determine an optimum course of action.

## STUDY REPORT ABSTRACT:

The product improvement program for the M60A1 tank was established to provide a cost-effective, near-term deterrent. Contrary to the purpose, the plan for conversion of all M60A1s to the improved M60A3s requires more than 10 years.

By performing a systems decision analysis on the problem, an optimum course of action was established. First, a revised procurement plan for the product improvements reduced the time to complete the acquisition by four years, and saves \$41 million in procurement costs. Second, an accelerated conversion program at Anniston Army Depot (AAD) provides sufficient capacity and the most cost-effective approach to convert the majority of the tanks. The last 30 percent of the conversion effort in the last five years of the program requires further economic analysis to determine the most cost-effective alternative between further expansion at AAD and initiating conversion at Maintz Army Depot (MAD), Germany, for the five-year period.

A model developed for the relevant cost parameters allows comparison of the two most cost-effective alternatives. Since the economic analysis is beyond the scope of this study, the model will be provided to the appropriate agencies for a follow-on comparison. The solution to this model will not impact on the program decisions recommended above, and will not preclude program initiation. Once the economic analysis has been completed, the program can be refined based upon the follow-on evaluation.

KEY WORDS: Procurement Plan (Leader-Follower); Conversion Program; Systems Analysis

MATERIEL    MANAGEMENT    PRODUCT IMPROVEMENT    TANKS    DECISION THEORY  
MAIN BATTLE TANK

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DONALD W. DERRAH, MAJOR, US ARMY

CLASS  
PMC 76-1

DATE  
MAY, 1976

APPLICATION OF PRODUCT IMPROVEMENTS TO THE  
M60A1 MAIN BATTLE TANK: A DECISION ANALYSIS

Study Project Report  
Individual Study Program

Defense Systems Management School

Program Management Course  
Class 76-1

by

Donald William Derrah  
Major US Army

May 1976

Study Project Advisor:  
Dr. Donald W. Hurta

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This study project report represents the views, conclusions and recommendations of the author and does not necessarily reflect the official opinion of the Defense Systems Management School or the Department of Defense.

## EXECUTIVE SUMMARY

The purpose of this study is to apply systems (decision) analysis (SDA) to a project management problem.

SDA, as used in this study, is an iterative transformation of data in a structured manner to arrive at a logical course of action to achieve an objective. The concept represents an orderly, procedural technique to formulate objectives, establish alternatives and evaluate those alternatives to deduce a model most suitable for collecting facts to provide a solution to a problem for which the SDA is conducted. Judgment still plays a very large part in structuring the analysis and making the decision.

The problem chosen for analysis is derived from within a tank product improvement program for the M60A1 main battle tank. In order to improve combat effectiveness for this tank, a program to develop certain components that will enhance performance was initiated in 1970. Since this tank will be in the inventory for at least 25 more years and represents a low-cost tank deterrent for any potential near-term threat, the program was considered prudent. As the final product, the M60A3, evolved from this process, a plan was established to procure and apply the remaining two high-dollar product improvements (PIs) to the M60A1 tank. This plan required over 10 years to convert the entire M60A1 tank fleet and cost \$660 million to procure the PIs, thus representing the contrary to a near-term and low-cost program.

After analyzing the problem and the environment, an objective, to identify an optimum M60A3 conversion program that will minimize total program costs while maximizing M60A3 tank availability, was established.



Two specific goals were recognized as means to achieve the objective. First, a procurement plan for the product improvements that will maximize quantities available for application and minimize procurement costs consistent with a reasonable risk program, and second, a conversion plan that will minimize fleet application time and cost, were identified as the two desired goals necessary to meet the program objective.

The next step was to examine all alternatives and provide a list of the feasible approaches conceivably leading to the best course of action. The problem is examined by addressing each of the goals separately. First, feasible procurement alternatives were selected: sole source to developer, totally competitive, and the leader-follower technique. Once the most appropriate method of procurement was established, three alternative options for quantity and rates were examined. These were categorized as high, medium and low risk programs associated with minimizing the total time required to procure the components.

The second part of the problem examines suitable methods and facilities available to convert the fleet. Options were representative of various feasible approaches.

An evaluation of the alternatives was the next step in the SDA. A clear selection of leader-follower type procurement evolves from the considerations and circumstances of the problem. A cost comparison for the high, medium, and low risk program options was conducted. Considering the cost, risk and schedule for each approach, the medium risk program provides the best balance. A \$41 million reduction in program cost from the original program estimate is achieved, and the schedule to complete the procurement is reduced by four years.



The second part of the problem eventually reduces the conversion options to the two most cost-effective approaches. First, Anniston Army Depot is selected to convert 3,580 M60A1 tanks which are scheduled to be retrograded as war reserve assets and positioned at AAD. This represents the majority of M60A1 tanks and is obviously the most cost-effective means for conversion. The last five years require a closer look. A quantity of 2,226 M60A1 tanks cannot be retrograded without replacements. Since these tanks are predominately located in Europe, the option to convert them at Maintz AD provides a reasonable alternative to converting them at AAD. An economic analysis is necessary to determine the most cost-effective approach between the two choices. A model was formulated for the cost parameters so that the two alternatives can be evaluated. Since data collection will require the combined efforts of numerous DARCOM agencies, which is beyond the scope and time available for this paper, the model derived in this paper will be forwarded to the appropriate agencies for a follow-on evaluation and refinement of the M60A3 conversion program.

#### ACKNOWLEDGEMENTS

Thanks for assistance rendered the author for coordination of the diverse government agencies and contractors, as well as administrative input, is extended to Major Miller, Executive Officer for the M60 Tank Development Office.

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Special aid was received from TACOM. Specifically, Mr. Norman Powers assisted in analyzing depot maintenance operations and facilities. Pat Martin has also been instrumental in providing tank requirements, distribution-redistribution plans, and considerations relevant to tank use for the Army over the next fifteen years.

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APPENDIX B: Army Tank Program (POM) Procurement

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APPENDIX E: Economic Model to Compare AAD and MAD Costs

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BIBLIOGRAPHY

## SECTION I

### Introduction

#### Purpose of the Study Project

The art of decision-making, a keystone of project management, involves the logical transformation of facts and judgments into an optimal course of action. An orderly formulation of all parameters into a rational structure, as well as documentation of all the inputs, analysis and conclusions, provides a pragmatic scientific aid to the decision-maker.

E. S. Quade has stated:

Military planning and strategy have always involved more art than science; what is happening is that the art form is changing from an ad hoc, seat-of-the-pants approach based on intuition and experience to one based on analysis and supported by intuition and experience . . . . (1:427)<sup>1</sup>

Quade further states:

. . . we may be so mesmerized by the beauty and precision of the numbers that we overlook the simplifications made to achieve this precision, neglect analysis of the qualitative factors, and overemphasize the importance of idealized calculations in the decision process. But better analysis and careful attention to where analysis ends and judgment begins should help to reduce the dangers. (1:427)

Explicit documentation of the writer's decision process provides a foundation upon which to base deviations, additions or deletions to the selected course of action when the output is subjectively viewed by other individuals involved in reviewing or implementing the decision.

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<sup>1</sup>This notation will be used throughout the report for sources of quotations and major references. The first number is the source listed in the bibliography. The second number is the page in the reference.



As Alain Enthoven has put it:

Ultimately all policies are made and all weapon systems are chosen on the basis of judgments. There is no other way and there never will be. The question is whether these judgments have to be made in the fog of inadequate data, unclear and undefined issues, and a welter of conflicting personal opinions, or whether they can be made on the basis of adequate, reliable information, relevant experience, and clearly drawn issues. (2:151)

The purpose of this project is the application of systems analysis to a specific project management problem as an aid to the selection of a course of action.

### Definitions

#### Systems Analysis.

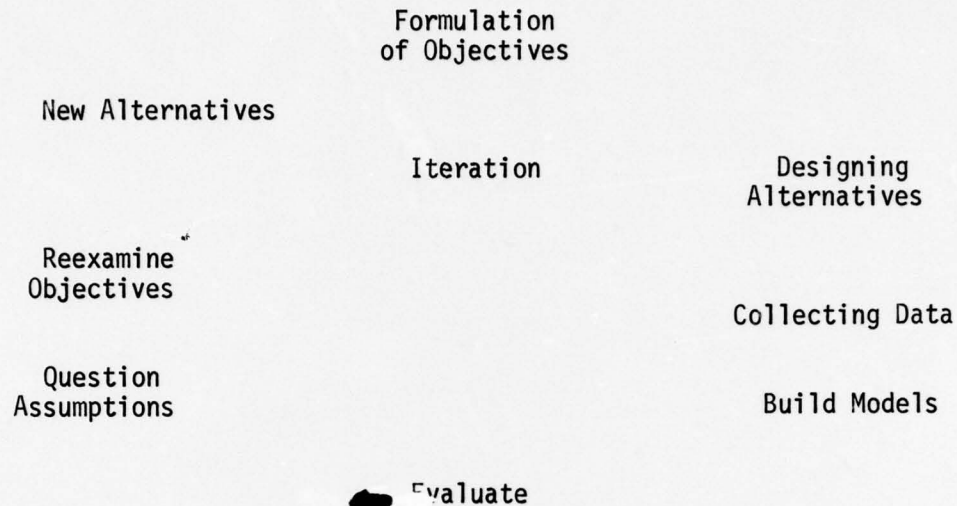
Tends to be thought of in terms of analytic techniques such as linear programming, game theory or some other operations research model. Variation in characteristics of specific problems tends to change the nature systems analysis portrays. It can best be described as a strategy, a perspective on applicable analytical tools, and a philosophy of how best to devise a framework and analyze a situation. Many iterations are common during each phase of the process, and between phases, to reinforce the structure or provide modifications. Like the top of an iceberg, documentation or results of the process merely reflect the final, precise output that surfaces after much informal, possibly subconscious, massaging of data has taken place under the surface to arrive at a logical conclusion.

E. S. Quade has defined systems analysis:

. . . as a systematic approach to helping a decision-maker choose a course of action by investigating his full problem, searching out objectives and alternatives, and comparing them in light of their consequences, using an appropriate framework--insofar as possible, analytic--to bring expert judgment and intuition to bear on the problem. (1:2)



Dr. Hurta, Defense Systems Management School, has described systems (decision) analysis as follows:



(Adapted from Quade and Boucher) (1:14)

The key to this model is the iterative nature of the procedure to arrive at the best portrayal of the problem and the analysis.

#### Environment:

The concept of environment stems from a systems approach where every system is a subset of a larger system, the suprasystem. Boundaries are present delineating each subsystem, but adaptation occurs both from changes in the subsystem on the environment and vice versa.

Kast and Rosenzweig state:

Organizations attempt to reduce environmental uncertainties . . . in a turbulent environment . . . organizations must develop a more adaptive, responsive system. (5:140)

Objective:

A broadly stated purpose will be the meaning applied by the writer of this paper.

Goals:

Goals will be used to describe standards of intermediate, desired outcomes of system subsets which are designed to enhance achievement of system objectives.

Limitations:

This word will be used to delineate physical boundaries prohibiting certain levels of accomplishment as impractical or impossible. These boundaries are rigid or difficult to change.

Constraints:

This word will describe boundaries which result from policy, normative values, or standards. Changes can and may occur in these boundaries based upon attitudinal changes or environmental circumstances.

Specific Goals of the Project

By utilizing a specific problem and applying systems decision analysis (SDA), program objectives will be formulated. The environment will be analyzed to determine feasible alternatives to accomplish program objectives. The structure or framework, to include models appropriate for each alternative, will be detailed. Finally, for models requiring data collection within the scope of this paper, conclusions will be drawn to determine the best course of action.

### Limitations of the Report

Since the collection of specific data needed in some of the analytical models will require detailed economic analysis from several support agencies not available in the time provided to complete this study, this project will provide a framework and logical structure for applying that input and will eventually be used as an aid to the project manager in selection of a course of action.

## SECTION II

### Present Situation

#### Background

In 1970, a product improvement program (PIP) was recommended for the M60A1 main battle tank. This program has resulted in eight major components being approved by the Army for incorporation into new production tanks and procured as kits for application to fielded M60A1 tanks.

The purpose of the program was to provide improved reliability, hit performance and night fighting capability to the main battle tank, M60A1, through evolutionary development consonant with state-of-the-art technology. Since a revolutionary tank design, namely, the XM-1, is at least five years away from fleet incorporation and will represent a small segment of our tanks until at least 1990, improvement to the M60A1 is deemed appropriate to counter the near-term threat and provide a viable opponent to technologically improved forces of other nations.

Some of the product improvements (PI) warranted early incorporation on an individual basis. Five of the product improvements are being procured (see Appendix A) and applied to all production tanks. Conversion of fielded M60A1 tanks to a tank model which will incorporate the five product improvements will be scheduled during normal overhaul, and the entire fleet will be equipped with all five product improvements (PI) by 1983.



The last three product improvements, yet to be approved for procurement, will be applied to the entire fleet (5,808 tanks) upon approval and will complete the transition of our main battle tanks from M60A1 tanks to M60A3 tanks.

The currently recommended program (see Appendix B) will take until 1988 to complete and is based upon a maximum yearly quantity of 600 tanks converted at Anniston Army Depot (AAD). This represents approximately two-thirds of AAD's present capacity of 972 per year. Approximately 200 tanks are scheduled for normal overhaul each year. Any other tanks beyond the 200 will not be of sufficient age to justify complete overhaul, but will be deferred from availability specifically for the conversion to M60A3.

#### Nature of the Problem

The more than 10 years required to convert the fleet at the currently planned rate seems contrary to the purpose of the conversion program. The development was based on the premise that the M60 series tanks will remain active as our main battle tank for at least 15 more years and will represent a major portion of the fleet during this period. As such, there is a need to improve tank performance and combat effectiveness of the M60A1 to keep pace with technological advances of other nations.

The sooner the fleet can be converted, the better the economic consequences and combat effectiveness for the Army. Therefore, within the environmental constraints and limitations, the program must be optimized to achieve the best course of action.



### SECTION III

#### A Systems Analysis of the Problem

##### Formulation of the Objectives

In the preceding section, I provided a synopsis of the problem to help orient the reader. In this section I will provide additional background by examining the environment in more detail to ascertain the validity of the stated problem and to provide a formulation of suitable objectives as a first step in solving the problem. This step in systems analysis requires many iterations in a complex system problem, but is time well spent, since identification of the true problem--not symptoms of the problem--can be a key to the solution. Furthermore, the objectives are the cornerstone to a good solution.

First, an examination of the issues is prudent. Other nations have developed advanced technology comparable to the state-of-the-art represented by the M60A3. Improvement in our tank fleet is warranted to keep pace with the advances by potential, future adversaries.

Other technical alternatives exist to provide this deterrent. The Army, through cost-effectiveness and affordability studies, has selected the M60A3 as the best alternative in the short run. This decision was based primarily upon early availability and low costs for the M60A3 as compared with other alternative systems equally effective. Test results have proven the system's performance.

This raises the question as to why the new tank (XM-1), a more effective tank, won't serve to meet the threat. The reason is the uncertainty in the initial availability of the new tank, since the system is still in the validation phase. Even approval of the new tanks must be viewed with uncertainty, since DSARC II is not scheduled until mid-1976.

With the need established, the question persists as to what environmental factors limit, constrain or provide uncertainties and consequences relevant to providing the selected system (M60A3).

There are two ways to provide an M60A3 to the US Army. First, new tanks can be produced as M60A3s, and secondly, the fleet of M60A1s can be converted to M60A3s.

In the first case, tank production capacity, although being accelerated rapidly, is faced with physical and technical limitations. If funds were available, production leadtimes would preclude expansion by more than 10 percent beyond the current M60A3 production rate in the immediate future. Two other ways to increase tank production would be long-range expansion of production rates and continuation of production at current rates. The fact that long-range plans call for a new tank (XM-1) would make expansion of capacity uneconomical, since M60A3 tank production is to be terminated in the near future. If production were not terminated as planned (in 1981), sufficient accumulation of M60A3s at the current production rate would not be available in time to provide an adequate deterrent. The maximum amount of M60A3s produced, from a cost-effective viewpoint, is 2,000.

This leads to the second means of providing an M60A3: that is, converting the total number (5,808) of M60A1 tanks, the baseline for an M60A3. This can be achieved by providing the three remaining product improvements to those M60A1 tanks in the field. Since the M60A1 is 90 percent of the M60A3, a considerable cost and time saving is achieved from utilizing the available M60A1s.

Hence, we have identified the problem by deducing the fact that our only means of providing a near-term, effective and adequate deterrent to the threat is by converting the M60A1 fleet to M60A3 tanks at the soonest possible time to supplement the mainstream of limited new production tanks.

How, then, should this problem be solved, and what are the objectives? If there were no environmental (time, money, or technical) limitations on the program, and if no policy constraints existed, it would suffice to devise a plan to procure all product improvements at one time and apply them immediately to all tanks at the appropriate strategic location which would provide an immediate combat-effective balance and mix. Costs would be minimized by avoiding inflationary trends and by savings realized from a large-quantity, economic buy. An immediate need for the large quantity would enhance competition and further reduce the cost. Obviously, this is not the case. The problem can best be analyzed by breaking it down into two parts.

The first part requires an examination of the considerations involved in procuring the product improvements remaining. The Laser Range Finder (LRF) and the Solid State Computer (SSC) comprise approximately 80 percent of the cost for the three remaining product improvements; and the third product improvement, the night vision devices, can be procured and applied at the most effective rate established for the critical product improvements (LRF and SSC). Therefore, this discussion will orient around procurement of the two most critical and costly product improvements.

Production leadtimes for the two critical product improvements, requiring 13 months for the developer and 18 months for a producer other than the developer who is unfamiliar with the technical data package, are technical limitations. Economic analysis has established the most economic production rate at 50 per month for one set of production tooling. Technical risks involved in quantities beyond that rate, coupled with inefficiency in costs, preclude the reasonableness of expanding beyond that limit. However, more than one producer or one set of tooling is possible.

New M60A3 production will require, on a first-priority basis, the same two critical product improvements. Since approximately 2,000 new tanks can be built, providing a segment of the fleet at a cost savings over latter conversion from M60A1 to M60A3, it is obvious that the product improvements will first be applied to the new tanks. Therefore, the availability of the critical product improvements for the conversion program will be based on procurement quantities minus the amount used for new production tanks.

In addition to the five months' additional leadtime for initial production from other than the developer, five more months will be necessary for administration of a competitive award. Proprietary rights, technical changes still in process, and the complexity of the system make initial production from other than the developer extremely risky.



Another issue concerns the fact that while the tank line funding ceiling in the POM is not an absolute, political constraints on the budget and public apathy toward increased defense spending make any fiscal expansion beyond this ceiling in the next five years unrealistic (see Appendix B). This precludes any serious consideration for options requiring funds beyond this limit. Priorities within the tank line are new tank production, a revolutionary new tank development program for the 1980's (XM-1), conversion of M48 tanks, and conversion of M60A1 tanks. Priorities within the various tank programs represent policy constraints which can be changed with appropriate justification. Funds for these programs may be altered based on uncertainties in the needs and changes in priorities. For example, the conversion program for the M48 tank is divided into two phases. The first segment, currently underway, provides a cost-effective source for reserve and guard forces. The completion of this phase is scheduled for early 1979. The second phase, for foreign military sales, is a requirement deserving review.

The problem, as stated, required early conversion to meet the near-term threat. The fund limitations and other competing tank program needs for the limited funds clearly point toward formulating a solution to the problem within the fund limits and that balances the need for early conversion with maximum efficiency in use of funds. In other words, minimizing procurement costs must be considered, along with achieving maximum availability of the critical product improvements at the earliest time.



Another constraint, low-rate initial procurement of the M60A3s, has been required so that production validation tests can be achieved prior to full-scale production. This places constraints on production or conversion rates until testing has demonstrated successful performance of the production hardware. Plans currently limit the rate produced during this period and preclude fielding of the system until after production validation, in early 1979. Uncertainties in the performance due to technical changes following development tests make eliminating this phase risky.

Maximum procurement competition is desirable from a legal standpoint as well as from an economic viewpoint. The procurement plan must maximize competition as soon as possible after reducing the technical risk by initial low-rate production from the developer.

In light of the limitations, constraints, issues and uncertainties (risks) described above, the first goal is an optimum procurement plan that will minimize costs and maximize product improvement availability to enhance the objective of early, cost-effective conversion for all tanks.

The establishment of an optimum solution to the first goal will result in a specific production rate and will delineate the total time for production. This is a prerequisite to selecting the best alternative for the second part. Once we know the optimum schedule for procuring the product improvements, we can examine the feasible means of applying the product improvements to determine the most efficient, economical

and combat-effective approach. First, let us examine the environmental considerations and establish the goal for the conversion program, the second part of our problem.

Tanks are predominately dispersed throughout the continental US and in Europe. Because we have applied previously approved product improvements incrementally, there are variations in tank models at each unit. This will require variations in the number of improvements required to upgrade a tank to an M60A3 within each unit proportionally to the mix of tank models assigned to that unit. Since each unit is constantly changing its mix by receiving new model tanks either from production or overhaul, it is difficult to predict an individual unit's mix at any future point in time.

The number of tanks available for overhaul and evacuation to the two depots currently overhauling tanks (AAD in the US and Maintz Army Depot [MAD] in Germany) varies each year, and depends upon the usage rate. There is an approximate total of 200 tanks per year overhauled, but a prediction for more than one year is difficult, as the units' usage requirements change over the years, making accurate forecasts of overhaul needs difficult. By extrapolation, the 200 tanks per year provides our best estimate from available data.

Based on currently planned M60A3 and XM-1 production rates and Army Acquisition Objectives (AAO), the M60A1 series tanks will be replaced on a one-for-one basis and evacuated to war reserve assets, located predominately at AAD, for conversion to M60A3 tanks. Some of these tanks will be transitioned to reserve and guard units eventually. By 1986, all M60A1 tanks will be replaced.

All new M60A3 or converted M60A3 tanks not retrograded are to be returned to dedicated M60A3 units to preclude continuation of the mixed fleets, generated by the incremental application of previously approved product improvements. This will avoid training, logistic, and maintenance problems. Materiel readiness policies require a replacement tank for any tank evacuated for conversion so that using units are not short tank requirements during conversion.

Fixed assets (organizations and facilities) with conversion capacity are available for the program. Some require expansion, facilitization or adaptation to conduct the required conversions. Associated with each alternative is a fixed cost and variable cost, depending upon the capacity desired per period of time. Other work requirements for these facilities, such as the AAD conversion program on the M48 tank, must be considered.

As previously stated, availability of funds is limited and other competing requirements beyond this program demand economy of scarce resources or minimizing the total cost of conversion. A transportation time/cost from tank origin to point of conversion and back to destination will influence the total conversion cost.

From the above considerations, we can conclude that tank availability for conversion, locations desirable for the conversion, variations in tank models and geographic locations all provide an impact on the cost and time for the conversion. Therefore, the second goal is to ascertain an optimum method for conversion that will minimize costs and time in consonance with the product improvement procurement plan and these other environmental considerations.

In summary, the objective is to optimize an M60A3 conversion program. This requires achievement of two goals: an optimum procurement plan and an optimum method for conversion. Attainment of these two specific goals will minimize total program costs while maximizing M60A3 tank availability, the program objective.

#### Feasible Alternatives

The most important step in selecting alternatives is to assure completeness of selection. Some alternative may appear remote in providing the best approach, but failure to include all possible alternatives can be perceived as incomplete or biased evaluation when the data are reviewed.

Two parts to this section will be necessary in order to address the two distinct goals formulated in the previous section.

Three conceivable approaches to the procurement plan include:

(1) sole-source to the developer for the total quantity; (2) totally competitive procurement; or (3) a combination of sole-source and follow-on competition (leader-follower).

Once the approach has been established, based upon the merits for each in light of the considerations previously outlined, a rate can be selected which will represent: (1) high risk rate; (2) medium risk rate; or (3) low risk rate.

The second part, or selection of alternative means to convert the fleet, includes the following alternatives:

1. Convert at Anniston Army Depot (AAD)
2. Convert at AAD and Maintz Army Depot (MAD)
3. Convert at Red River Depot (RRD) and AAD
4. Convert at AAD and MAD and RRD
5. Convert at AAD and General Support Maintenance (GSM)
6. Convert at AAD and GSM and MAD



Obviously, this does not include all combinations possible; nor does it include such possibilities as establishing a new location or use of numerous other support facilities of a similar nature to the cross section listed above. The alternatives do, however, establish the most credible approaches, considering the gamut of procedurally feasible approaches. The evaluation will provide clear rationale for eliminating any and all alternatives from consideration, except numbers 1 and 2, listed above, because of the circumstances. A more detailed comparison for the two alternatives most likely to satisfy the objective is necessary to arrive at the final selection.

#### Alternative Evaluation

This section will address the three segments of the decision in the same sequence as they were presented in the preceding section. The first question to be answered is: "Which method of procurement will be used for the LRF/SSC product improvements?"

A totally sole-source program with the developer entails the least technical risk. Since the developer has gained engineering experience so important in consideration of the complex, technical equipment involved, a sole-source procurement appears attractive. On the other hand, a sole-source approach precludes competition, a primary means to reduce costs. Another consideration is availability of the product improvements, or how soon the 5,808 systems can be procured for conversion, remembering that the first priority is the 2,000 systems required for new production tanks. An economic analysis has been conducted by the developer. Based

on one set of tooling, the most economical quantity has been defined as 50 per month. A maximum limit associated with high risks in quality has been established at 75 per month. At either one of these rates, a sole-source contract with the developer would require more than ten years.

Totally competitive procurement provides maximum incentive for cost reduction on the initial procurement. Once a winner has been selected and this contractor establishes a production base for one or more years, the problem developed is similar to the sole-source position of the developer: Any other competitor trying to bid on a later contract will not have a truly competitive price without establishing unrealistic estimates because of the learning curve difference between the two contractors. A time delay to move the tooling and higher technical risks during any initial production by another producer on a later contract is a disadvantage of a totally competitive approach. The one most important detriment of a totally competitive approach is the technical performance of the initial product. There has not been a demonstration of the TDP producibility. The risk associated with initial production by other than the developer is critical. Of course, risk associated with performance increases the uncertainties of schedules. Assuming that the quantities identified by the developer as most economical (50 per month), and that the maximum (75 per month) will be no larger for any other producer, a totally competitive contract to one producer will not reduce the 10-year schedule.

The third alternative, a leader-follower approach, combines the attributes of the first two alternatives. By buying a second set of tooling for another producer, the production rate can be doubled. The cost of the tooling is less than 2 percent of total program costs, while more than 10 percent of program costs can be saved through the use of two sets of tooling.

Leader-follower is not the only means of using two sets of tooling. Two sets could be used for a sole-source or totally competitive procurement. A sole-source approach would be cost prohibitive. The totally competitive approach with two sets of tooling is very risky, since we lose the assurance of initial production with the developer.

Advantages of the leader-follower approach include reduction in risk by initiating low-rate initial production (LRIP) with the developer. This will make deliveries of product improvements more certain to assure tank line continuity for production tanks, and provide verification that the product improvements will perform as intended. Two producers for several years will provide long-term competition. Government supervision of leader assistance to a new producer (follower) will increase the opportunity for the follower to compete with the developer. After the follower has gained a reasonable degree of experience (three years of production), a multi-year, competitive buy at the end of the training period for a large quantity will provide maximum incentive for cost reductions.

The two sources will provide larger quantities at an early time, thus avoiding the out-year inflationary cost impact. This will also provide the opportunity to increase the near-term tank effectiveness, if and when the product improvements are applied to the tanks.



Flexibility is increased with the two sets of tooling. Other potential requirements, such as PI application for other tanks (M48 and M60), mobilization, foreign military sales, or continuation of new tank production, provide justification for a broad production base.

The second segment of the evaluation addresses the product improvement production schedule. Remembering the goal for the procurement plan of maximum quantities at low cost, two schedules, each accelerating production which inherently reduces the cost, can be generated. These two plans are based on the leader-follower concept and will be compared to the current plan. All three schedules are shown at Appendix C.

During the formulation of the program objective, specific uncertainties were presented. In order to conduct a detailed analysis of the three plans, these uncertainties must be assessed and assumptions made as to the most probable occurrence.

Due to congressional review of the program, FY 76 funds have not been released for this procurement. The best estimate at this time is that the contract for the LRF/SSC product improvements could be awarded by 1 July 1976. Based upon this assumption, the program would incorporate the following milestones:

- |   |                               |
|---|-------------------------------|
| 1. Award LRIP contract for LRF/SSC                          | July, 1976                    |
| 2. Sole-source production leadtime to developer             | July, 1976-August, 1977       |
| 3. Applications of product improvements to tank             | September, 1977-January, 1978 |
| 4. Production validation test--contractor                   | January-July, 1978            |
| 5. Production validation test--government                   | July, 1978-January, 1979      |
| 6. Production validation IPR (type classification standard) | February, 1979                |



This schedule is optimistic, or success-oriented; however, administrative allowances have been considered, and some slack time has been incorporated to provide the most realistic estimate. Judgments are based on an analysis of historical schedules of a similar nature and expert opinion from the project manager team members (contractors, test agencies, project office, DA sponsor).

The second uncertainty is approval of the recommended procurement approach (leader-follower [LF]). Since the original plan (number 1) has been submitted utilizing the LF approach and has received support throughout the Army, it is reasonable to assume this procurement technique will be approved. A Secretarial D&F and an advance procurement plan are currently being reviewed by the Department of Defense.

Successful LRIP is not a certainty; however, the successful completion of developmental testing lends credibility to support the assumption that production testing will result in approval of the tank at the production validation. Further support of this assumption is gained by initial developer production reducing the LRIP risk.

The last major assumption is that sufficient funds will be made available to support any recommended plan to accelerate production rates. Total program savings justifies release of additional funds. On the other hand, it is essential that recommended program plans consider total tank requirements and priorities. In other words, affordability limits restrict the reasonableness of funds available to the program.

More specifically, the funds must be identified. Until recently, the total M48 tank conversion program was of a high priority than the M60A3 program. The user has reviewed this in light of the urgency of meeting the near-term threat with the M60A3. The first segment of M48 conversion will be completed by early 1979, the first year in which acceleration of the M60A3 program can be implemented because of physical production limits and LRIP constraints on initial production quantities for the product improvements. The second segment of M48 conversion is most likely to be used for foreign military sales (FMS). Conducting this M48 tank conversion through the provisions of a conditional undertaking (requiring payments for FMS as needed), the funds programmed for the second segment of M48 conversion could be released for the M60A3 program. (See Appendix B.)

Based upon these assumptions, two acceleration programs can be generated. The two plans represent variations in the degree of risk associated with maximizing procurement and minimizing costs. Plan number 2 (Appendix C, Annex 2) is a medium risk, accelerated schedule in which deliveries will not exceed the most economical rate (50 per month) for each producer. Plan number 3 (Appendix C, Annex 3) will accelerate the schedule by producing at rates considered extremely risky in terms of quality.

In order to compare these two plans and the original plan (Appendix C, Annex 1), three criteria are considered: risk, schedule and cost. Plan number 3 clearly provides the best schedule for delivery of product

improvements; but remembering the objective to provide early availability of tanks, the ability to apply the product improvements to the tank must also be considered. A more detailed analysis of conversion alternatives is provided in the next section of the evaluation, but a cursory review of application requirements shows the plan number 3 schedule to be beyond the limitations of a cost-effective conversion program.

If risks were not considered, Plan 3 maximizes cost savings. However, extreme technical risks are associated with this accelerated production rate for plan 3. An extremely rapid production buildup to 800 systems prior to the production validation is required. Therefore, the follower will be using a technical data package that has not been proven by a limited production run. The follower will be committed to the production of a significant quantity for a sophisticated product without benefit of any experience relative to the product's design or producibility. The consequences would be the expectation of a significant quantity of engineering change proposals (ECPs) from two sources for producibility changes.

Program costs and risks can be evaluated by quantifying both parameters and conducting an expected value analysis. The concept of expected value corresponds to that of a weighted mean,  $\bar{X} = \sum FX/N$ , where the probability,  $P(X)$ , is equivalent to the relative frequency,  $F$ , and  $N = 1$ , since the sum of the probabilities is equal to 1. (13:112)

Cost estimates are based on respective schedules and Army-approved escalation rates. Recognizing limitations to the discrete estimate because of uncertainties in escalation rates, competitive savings and potential variations in learning curves; these discrete estimates provide a relative cost comparison for the three plans. These estimates are optimistic in nature, since the schedule is success-oriented.

At the same time, a pessimistic cost estimate can be established. An arbitrary 20 percent increase in the optimistic estimates provides a best estimate of potential problems. These include delays in delivery schedules, increases in provisioning requirements, and more maintenance actions. The relative impact on the three plans is more significant than the degree of accuracy of the 20 percent estimated increase.

Next we can assign probabilities to the two discrete cost values (optimistic and pessimistic), which are based on the amount of risk involved in each plan.

The expected value computation will result in a quantifiable comparison of the three plans in terms of risks and costs. Keeping in mind the fact that quantifiable methods are an aid to the judgmental evaluation of the decision-maker, the details of the analysis follow:

#### Expected Value Analysis

<u>Alternative</u>	<u>Risk</u>	<u>Optimistic<sup>2</sup> Value (\$Mil)</u>	<u>Probability</u>	<u>Pessimistic Value</u>	<u>Probability</u>	<u>EV</u>
Plan 1	Low	\$660	.95	.792	.05	667
Plan 2	Medium	619	.85	.743	.15	638
Plan 3	High	608	.60	.730	.40	657

<sup>2</sup>Cost estimates were prepared by project management office and Hughes Aircraft Corporation (the developer) cost analysts using consistent and approved criteria for each estimate.



Since the goal was to accelerate procurement while minimizing costs, Plan 2, with the minimum expected value for program costs and the four-year reduction in program schedule, provides the best plan, balancing costs, schedules and risk. This approach optimizes the procurement plan, the first step in achieving our objective.

The final evaluation concerns application of the product improvements to the M60A1 tank fleet. First, assumptions must be formulated. The most important assumption is that the optimum procurement plan developed above is approved and implemented as planned.

Secondly, the quantity of tanks programmed according to the AA0 and the planned geographical distribution will not change significantly to upset the composition of the fleet strategic mix and balance. Inherent in this assumption is the requirement for new tanks, XM-1s and M60A3s, to meet planned delivery schedules (Appendix B). This will release M60A1 tanks for conversion and transition to war reserve assets, guard or reserve units as scheduled. (6:15)

Another assumption is that requirements for the use of facilities under consideration for the M60A3 conversion will not be taken for other higher-priority programs possibly unknown at this time.

Red River Depot (RRD) will be used for the M113 conversion program. M48A5 and M551 conversion and overhaul programs in FY 79 and beyond will not take precedence over M60A3 conversion.

No overhaul will be conducted at MAD after FY 78. Overhaul of all M60A1 tanks beyond FY 78 will be conducted at AAD. All tanks retrograded will be delivered to AAD, regardless of overhaul or conversion status.

Based on the first assumption, a specific, yearly quantity of LRF/SSC are available to be applied to M60A1 tanks in an optimum conversion program. These quantities, by year, are:

<u>FY</u>	<u>Conversion</u>	<u>Production</u>	<u>Others</u>
77	18	37	10 (FAT, Spares, TNRS)
78	44	259	6 (TNRS)
79	301	649	
80	164	786	
81	919	171	
82	1090		
83	1090		
84	1090		
85	<u>1092</u>	<u>          </u>	<u>          </u>
	5808	1902	16
GRAND TOTAL: <u>7726</u>			

The problem now is to determine the sequence, location and schedule for the M60A1 tank conversion.

One alternative not listed is to store some of the product improvements and convert at some rate less than the optimum scheduled availability for the product improvements. This alternative was eliminated because early availability of M60A3s is part of the program objective. If a rate of application other than total product improvement availability was most efficient from a conversion standpoint, the loss in combat

effectiveness resulting from M60A3 delay would make this alternative less than optimum. Furthermore, storage requirements, such as facilities, packaging and shipping, would offset the conversion cost savings. Additional testing of stored units and failure corrections for systems exceeding their shelf lives would be detriments of this approach.

As previously mentioned, M60A1 tanks are retrograded to AAD. Approximately 200 tanks per year will require overhaul. These tanks are the oldest models, M60A1s, and require the most conversion effort. More product improvements are required for these tanks than for newer models.

The abundance of the five product improvements not yet applied, but procured, is located at AAD. Since the oldest tanks require the most product improvements, conversion is facilitated at AAD. The central supply point at AAD permits configuration audits during disassembly and avoids the need to conduct long-lead audits to determine the product improvements necessary. If conversion were at another location, the long lead time and shipment of the appropriate product improvement mix to a location of application could cause program delays and unnecessary expenses, since the tank will be shipped to AAD, anyway. The more decentralized and dispersed the application points, the greater the risk that the appropriate product improvements at the appropriate time will be available. This is especially critical for the oldest tanks requiring the most conversion.

These tanks are all programmed to be overhauled prior to 1985. The savings realized by combining overhaul and conversion are substantial because the time and effort to disassemble the tank for the overhaul and the conversion will be simultaneous. Therefore, it is logical to begin any alternative program for conversion with the oldest tanks scheduled for overhaul at AAD.

At the same time, a quantity beyond the 200 per year are retrograded to AAD for transition to war reserve. This quantity varies, depending upon production and replacement rates for tanks. However, converting this quantity at AAD has the following advantages. There are no transportation charges specifically required for the conversion effort. Use of available capacity at AAD avoids facilitization and tooling for conversion. There is no cost to return the tanks to using units. Since the tanks will remain in war reserve, or be sent to guard or reserve units, this will minimize the impact on materiel readiness or combat effectiveness. Therefore, any alternative program, in order to be the most cost-effective and involve minimal conversion time, will have to include a fixed amount of tanks--those planned for overhaul and war reserve--for conversion at AAD.

The planned retrograde to AAD and scheduled LRF/SSC product improvement delivery schedules are shown below:

<u>FY</u>	<u>Retrograde of Tanks</u>	<u>LRF/SSC Available</u>	<u>Excess Tanks</u>	<u>Excess LRF/SSC</u>
77	87	18	69	0
78	139	44	95	0
79	390	301	89	0
80	225	164	61	0
81	341	919	0	264 <sup>3</sup>
82	600	1090	0	490
83	600	1090	0	490
84	600	1090	0	490
85	600	1092	0	492
	<u>3582</u>	<u>5808</u>	<u>314</u>	<u>2226</u>

<sup>3</sup>578 - 314 for conversion of previous years' tanks.



During the first four years, more tanks (314) are available at AAD than the optimum availability for LRF/SSC. Since excess LRF/SSC (578) are procured in FY 81, the 314 tanks retrograded but not converted can most efficiently be converted at this time. The total conversion for FY 81 would then be 665 tanks, which is within the present conversion capacity of AAD. Starting in FY 81, excess LRF/SSC availability occurs. There will be a need to find an optimum conversion program for the additional 264 LRF/SSC assets acquired in FY 81 and accumulating to 2,226 LRF/SSC assets by FY 85.

The following analysis will consider those feasible alternatives previously listed to determine the optimum conversion for the remaining 2,226 LRF/SSC product improvements to be applied to the M60A1 series tanks.

Turning to the problem of which tank models should be converted leads to a discussion of the considerations. The baseline for converting the oldest tanks first at AAD is sufficient justification for establishing the sequence of oldest tanks first. The low-mileage tanks not included in the baseline are M60A1 (RISE) tanks. These tanks provide the next best model to an M60A3.

One viewpoint on the conversion program is to concentrate conversion on the best tanks first. If this approach were taken, the economical advantages of first conversion at AAD would be lost. Furthermore, the tank effectiveness during the conversion period would be centered in a small segment of the fleet. Having M60A3 tanks and low-mileage, reliable M60A1 (RISE) tanks is better for overall effectiveness than high-mileage, unreliable M60A1 tanks and M60A3 tanks.

Another consideration for determining which models should be converted first is tank availability. During the conversion period, removal of M60A1 (RISE) tanks would reduce effectiveness during this period or require additional floats to replace RISE tanks removed for conversion. On the other hand, the oldest tanks are replaced by attrition as new production tanks arrive at using units. Even a field application program would require the technical skills, tools and facilities of general support maintenance. This would put the tanks out of service during the conversion period and require replacement tanks.

From which location the tanks should be converted first is the second part of the problem. USAREUR, or tanks located in Germany, is the highest-priority area for tank assets. Basing the conversion sequence on this aspect, alone, would suboptimize the program. If all tanks were converted in USAREUR first, the economic advantages of converting tanks at AAD as they are retrograded from all locations would be lost. Basing first conversion at AAD does not neglect the priority of USAREUR. The most effective portion of our fleet is from new production. Most of the new production tanks will be assigned to dedicated units in this area. XM-1, production M60A3s and M60A2s will supplement the M60A1 (RISE) tanks during the conversion of the older M60A1 models. If we also dedicated our conversion program to this geographic area, the strategic balance for tank effectiveness would be extremely one-sided.

The last problem concerns which facilities should be used to perform the conversion. Again, the conversion for the 3,580 oldest tanks is established at AAD, minimizing tank conversion time and cost while enhancing tank availability. Since there are no excess LRF/SSC assets until 1981, the location selected will be used for a five-year period, 1981 to 1985. The requirement during this period is to convert 2,226 tanks at a rate compatible with the availability of LRF/SSC product improvements, as shown below:

<u>FY</u>	<u>LRF/SSC Available</u>
81	264
82	490
83	490
84	490
85	490
	<hr/>
	2266

For clarity purposes, the six most feasible alternative combinations for conversion locations are shown again:

1. Convert at AAD
2. Convert at AAD and MAD
3. Convert at RRD and AAD
4. Convert at AAD and MAD and RRD
5. Convert at AAD and GSM
6. Convert at AAD and MAD and GSM

The first feasible approach considered is conversion at GSM in addition to depots (alternatives 5 and 6).

Alternative 6 converts at two depots. AAD would convert the 3,580 tanks being retrograded prior to the end of 1985. MAD would convert a segment of the 2,226 tanks based on their present capacity of approximately 100 per year from 1981 to 1985. The remaining quantity, 1,726 M60A1 RISE tanks primarily located in USAREUR, would be converted at GSM.

Alternative 5 converts 3,580 tanks at AAD, while the remaining application is done at GSM.

Alternative 6 can be eliminated on economics, alone. For such small quantities over a five-year period, establishing three operations for conversion would be uneconomical. Furthermore, any combination including levels of program application below depot is deemed a high risk from a technical standpoint. The fact sheet at Appendix D provides a detailed analysis of the technical requirements, costs, skills and problems involved in a GSM conversion program. This technical document was prepared by Chrysler Defense Engineering, the M60 tank systems engineering contractor.

In addition to the high technical risk and expansion costs for a GSM operation for such a limited period, the schedule for completion by 1985 is based on the optimum procurement plan. There would be no reduction in the schedule by converting at GSM.

Management and control risk for a GSM program include: coordination of budget requirements for numerous organizations, training and technical assistance programs from contractors and depot, and inventory control for decentralization of product improvement requirements.



The next alternative considered, alternative 4, is a combination of three depots. Two are located in CONUS (AAD and RRD), while MAD is located in USAREUR. This approach was included to assure completeness of the analysis. Based upon the fact that 3,580 tanks are most economically completed at AAD, the facilitization of more than one other operation for conversion would violate the economies of scale principle and would not be the most cost-effective approach. Furthermore, the fixed schedule established for LRF/SSC product improvement availability precludes expediting M60A3 tank availability potentially achievable from increased conversion capacity of three operations.

Alternative 3 converts at two CONUS depots, AAD and RRD. Using AAD for the base conversion as previously discussed, RRD would perform all conversion for the remaining 2,226 tanks. The merits of this approach include totally-CONUS-based conversion; no impact on balance of payments for conversion costs; more jobs in the US; less transportation costs and time for product improvement delivery; strategically secure base for conversion; and flexibility for mobilization. However, the majority of the 2,226 tanks requiring conversion are located in USAREUR. Transportation costs and time to return these tanks to CONUS would be extreme. These tanks would have to be replaced by float vehicles from CONUS war reserves. There is no depot operation currently being conducted at RRD. Maximum facilitization would be involved. The M113 dieselization program has tentatively been planned for RRD. The burden to initiate two major conversion programs for a new organization during the same period would be a detriment of this approach.

Another approach to converting at two depots is contained in alternative 2. The major difference is the location of MAD in USARUER, which provides better distribution of facilities in relation to the location of the assets to be converted. Of course, the advantages discussed above of two US-based depots are disadvantages of operations at MAD in addition to AAD.

The major advantages of MAD over RRD are the experience and facilitization for M60 tank work, proximity to the tanks, and the avoidance of risk inherent in initiating two major conversion programs at the same time. These advantages result in cost savings, increased tank availability and lower risks.

Alternative 1 converts all 5,808 M60A1 tanks at AAD. The conversion program for the initial 3,580 established sunk costs for AAD; economies of scale by expansion at AAD maximize reduction in facilitization costs. Present capacity of 972 tanks per year at AAD approaches the maximum conversion requirement. Based on the assumption that further M48 conversion during FY 79 and beyond will be funded by FMS, the cost for expansion required to conduct all M60A3 conversion is minimized at AAD. On the other hand, the additional conversion beyond the 3,580 requires those tanks deployed in USAREUR to be shipped back to CONUS, and replacement tanks shipped to the using units.

An analytical tool to aid in quantifying the parameters impacting on the decision is a decision attribute model. Values are based on judgment; but this model provides a clear and concise method of comparing the alternatives to aid the decision-maker.

The parameters of significance in optimizing the conversion plan are costs, schedules and risks. Weighting each parameter is difficult, but reasonable values are to consider them equal, since each one can have a major impact on the goal.

A decision attribute model for the conversion program follows:

	<u>A l t e r n a t i v e s</u>											
	1		2		3		4		5		6	
(.33) Cost	1	.33	2	.66	2	.66	4	1.32	3	.99	4	1.32
(.33) Schedule	5	1.65	4	1.32	6	1.98	3	.99	1	.33	2	.66
(.33) Risk	1	.33	1	.33	2	.66	3	.99	4	1.32	4	1.32
TOTALS:	2.31		2.31		3.30		3.30		2.64		3.30	

The first column rank orders the six alternatives for each parameter. The second column weights each alternative by multiplying by the percent of importance attributed to each parameter (i.e., .33 each). The second column is the product of the multiplication. This column is summed and the totals provide a quantitative means to compare the alternatives. The larger

the differences in the finally derived values for each alternative, the more distinct is the confidence in the quantitative results. The values used in column one correlate the lowest cost, risk and schedule with the lowest value. For example, the alternative with the lowest cost would receive a (1) in column one opposite the row for "cost." If two alternatives are equivalent in rank, they will receive the same value in column one. A check on the sensitivity to changes in parameter values can be accomplished to improve the objectivity.

If we had to differentiate between the importance of cost, schedule and risk, schedule would be least important in this case. Overall completion schedule is based on the procurement plan. The only differentiation of schedule in this decision is total time to convert, which is relative to time from destination to conversion facility, and time to convert, which would vary in relation to the learning curve or experience at each facility. Therefore, we will reduce the value assigned to schedule to .20. Since risks are nebulous compared to cost, the increased weight gained by reducing the value in the rank order of the alternatives in regard to schedule will be added to the more definitive value for cost. Thus, the new decision attribute model follows:



		<u>A l t e r n a t i v e s</u>											
		1		2		3		4		5		6	
(.46) Cost		1	.46	2	.92	2	.92	4	1.84	3	1.38	4	1.84
(.20) Schedule		5	1.0	4	.80	6	1.20	3	.60	1	.20	2	.40
(.33) Risk		1	.33	1	.33	2	.66	3	.99	4	1.32	4	1.32
TOTALS:		1.79		2.05		2.78		3.43		2.90		3.56	

The sensitivity analysis assists in supporting conclusions that alternatives one and two are significantly better than any of the other approaches. In this case, alternative one has a slight quantitative advantage; however, the difference (15 percent) compared to the next best solution's difference (55 percent) is insignificant.

## SECTION IV

### Conclusion

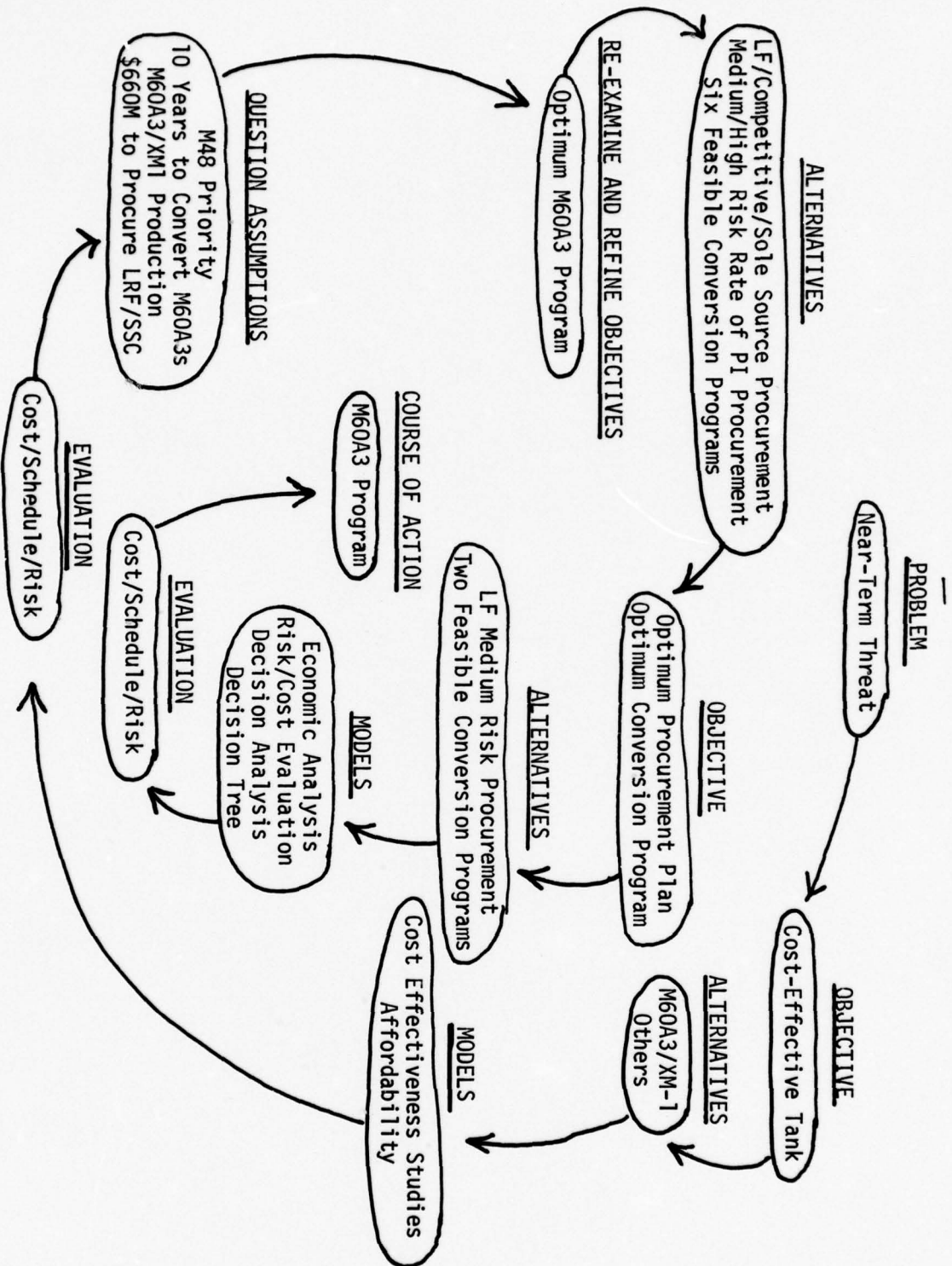
A diagram best depicts the iterative process of systems (decision) analysis, from formulation of the problem to establishing a course of action for this specific subject.

The diagram shown on the following page is self-explanatory and traces the essence of the process developed in this paper.

The procurement plan at Appendix C, Annex 2, is considered an optimum schedule to reduce cost without incurring unacceptable program risk. The plan utilizes two producers and completes production in 1985. \$41 million in cost and four years in time are saved by this plan.

The conversion program cannot be completely formulated from the available data with as much confidence as the procurement plan. From the available data, a conversion of 3,580 tanks at AAD is concluded as an optimum baseline, when considering costs, tank availability and risks. Selection of the optimum conversion program for the remaining 2,226 tanks requires an economic analysis of the two most cost-effective approaches, AAD and MAD. At Appendix E is an economic model depicting the parameters involved in the two alternatives. In essence, the choice is between conversion expansion costs to facilitate MAD, avoiding the shipment of replacement tanks to USAREUR, and conversion at AAD, requiring the shipment of replacement tanks, but minimizing facility expansion costs. Since both alternatives provide equivalent

# DIAGRAM OF DECISION PROBLEM



availability of tanks, the most economical approach will complete the optimum solution for an M60A3 conversion program to provide the Army the best course of action to meet the near-term threat.

To summarize the evaluation and conclusions, an analytical tool called a "decision tree" has been formulated. This provides an objective means to quantify our subjective evaluations of values and probabilities in an aggregate manner to support our conclusions. Values attached to each decision branch represent numerical equivalents to those costs derived from the preceding evaluation. Probabilities assigned to each path are equivalent to the risks associated with each path. The decision tree allows us to determine an optimum path based upon expected values calculated for each branch. The tree and calculations follow at Appendix F. (13:169)



# A P P E N D I X A

## PLANNED PRODUCTION AND CONVERSION FOR M60A3 TANKS

### M60A3 Production

FY 76  
77  
78  
79  
80  
81  
82  
83  
84  
85  
86  
87  
88

17  
20  
259  
649  
786  
171

T-142 TLAC

AOS

RISE ELECT PASSIVE

### M60A3 Conversion

Year each Product Improvement Application to  
M60A1 Tanks Completed

LRF SSC

Total Production: 1902  
Total Conversion: 5824\*

Total M60A3: 7726

### Nomenclature for Each Product Improvement

T-142	-- Track
TLAC	-- Top Loading Air Cleaner
AOS	-- Add-on Stabilization
RISE	-- Reliability Improved Selected Equipment Engine
ELECT	-- 650 Amp Oil Cooled Alternator and Solid State Regulator
PASSIVE	-- Passive Night Vision Devices
LRF	-- Laser Range Finder
SSC	-- Solid State Computer

\*Total conversion includes 5808 tanks and 16 units for training.

**ARMY TANK PROGRAM (POM) PROCUREMENT**

As of 15 March 1976  
Budget Quantities and Costs  
(\$ in Millions)

	<u>M60A1 Production</u>		<u>XM-1</u>		<u>M48A5</u>		<u>M60A3 Production</u>		<u>M60A3 Conversion</u>	
	\$	Accum Qty	\$	Accum Qty	\$	Accum Qty	\$	Accum Qty	\$	Accum Qty
FY	\$5829	5879								
77			\$ 81.2	1868	\$179.3	296	\$ 8.7	50		
78			59.7	2232	397.3	892	27.1	362		
79			92.9	2652	500.4	1678	54.7	962		
80			93.8	3060	113.0	1902	56.8	1562		
81				822			59.8	2162		
82				1182			62.0	2762		
83				1542				3362		
84				1902				3962		
85				2262				4562		
86				2622				5162		
87				2982				5762		
88				3312				5808		
TOTALS:	\$5829	5879	(Not Avail)	3312	\$327.6	3060	\$1190	1902	\$269.1	5808

# A P P E N D I X   C

## LRF/SSC ALTERNATIVE PROCUREMENT PLAN SCHEDULES AND COSTS<sup>1</sup> (\$ ESC)

	<u>Plan 1</u> (Low Risk)		<u>Plan 2</u> (Medium Risk)		<u>Plan 3</u> (High Risk)	
	<u>QTY</u>	<u>\$(mil)</u>	<u>QTY</u>	<u>\$(mil)</u>	<u>QTY</u>	<u>\$(mil)</u>
<u>FY</u>						
76	79	\$ 21.4	65	\$ 19.7	65	\$ 19.2
77	309	43.6	309	39.1	399	52.4
78	950	77.0	950	77.1	1260	97.6
79	950	73.3	950	73.3	1400	103.9
80	600	45.4	1090	82.3	1000	71.7
81	600	45.7	1090	80.0	1200	86.3
82	600	46.5	1090	81.0	1200	87.6
83	600	47.4	1090	82.2	1200	89.0
84	600	48.5	1092	84.0		
85	600	49.8				
86	600	51.1				
87	600	52.5				
88	638	57.5				
TOTAL:	<u>7726</u>	<u>\$659.7</u>	<u>7726</u>	<u>\$618.7</u>	<u>7726</u>	<u>\$607.6</u>

<sup>1</sup>Costs provided by PM-M60 and HAC cost analysts. Consistency in methodology and approved parameters were utilized.

## APPENDIX C

PLAN ]

M60A1 P1 LASER/COMPUTER PRODUCTION

HEV 3-10-76

	1976	1977	1978	1979	1980	1981 - 1988
FY 1976 GO AHEAD	49	JFMAMJJASONNDJFMA	JFMAMJJASONNDJFMA	JFMAMJJASONNDJFMA	JFMAMJJASONNDJFMA	JFMAMJJASONNDJFMA
LEADER - DELIVERIES		START DEL IN 13TH MONTH	J 8 8 1010 10			
FAT						
PVT C						
PVT G						
OT-III						
FY 1977 GO AHEAD	30					
LEADER - DELIVERIES		START DEL IN 14TH MONTH	10 10 10			
FY 1977 GO AHEAD	309					
LEADER - DELIVERIES (259)		START DEL IN 14TH MONTH	20 20 20 20 20 20 24 25 25 25			
FOLLOWER - DELIVERIES (50)		START DEL IN 18TH MONTH	2	3 5 7 13 20		
FAT						
IP T						
FY 1978 GO AHEAD	950					
LOW BID DELIVERIES (570)		START DEL IN 14TH MONTH	30 40 50 50 50 50 50 50 50 50			
HIGH BID DELIVERIES (380)		START DEL IN 14TH MONTH	24 24 33 33 33 33 33 33 34 34			
FY 1979 GO AHEAD	950					
LOW BID DELIVERIES (570)		START DEL IN 14TH MONTH	50 50 50 50 50 50 50 50 40 40			
HIGH BID DELIVERIES (380)		START DEL IN 14TH MONTH	32 32 32 31 31 31 32 32 32 32			
FY 1980 GO AHEAD	5438					
WINNER DELIVERIES (5438)		WINNER TAKE ALL - 4 YEAR MULT YR 600 PER 150 PER MONTH THRU 1938				
PRODUCTION TANKS	1902	2 3	3 4 5 6 7 7 20 20 20 20 20 20 24 25 25 25			
KITS	5808	4	3 5 6 3 3 4	3 5 7 13 20	10 29 29 29 29 29 29 29 29 27 27 27 15 13 13 14	3 3 2
TRAINING, FAT, ETC	16	2	2 10	2		29 50 50 50 50 50
TOTAL	7776					
GO AHEAD FY	338	76	77	78	79	80
LEADER - DELIVERIES	50					
FOLLOWER	1140	3 8 10 10 10 10 10 10 20 20 20 20 20 24 25 25 25				
LOW	760					
HIGH	5438					
WINNER	7776					



# ANNEX 2 APPENDIX C

PLAN 2

MS0A1 P1 LASER/COMPUTER PRODUCTION

REV 4-28-76

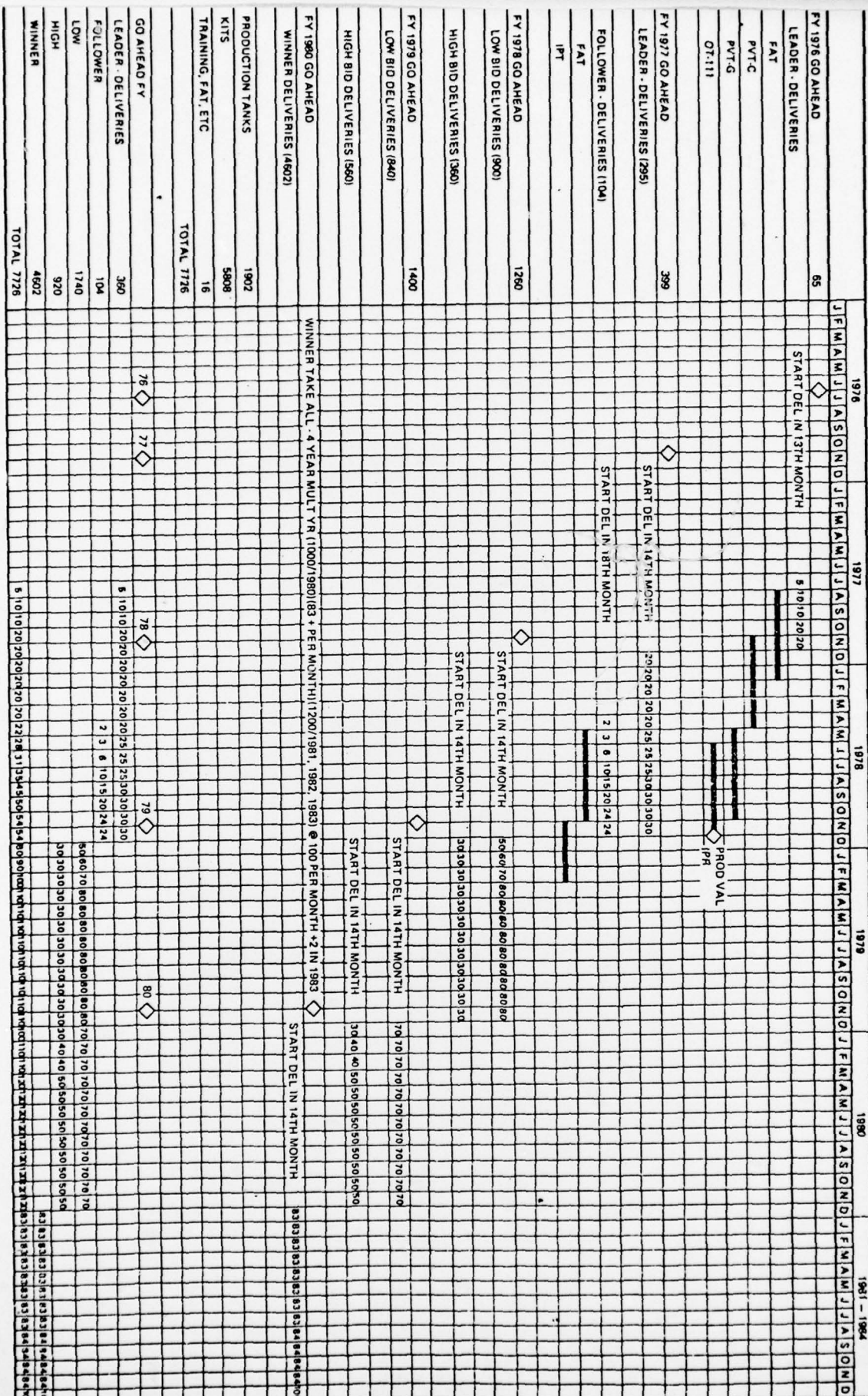
	1976	1977	1978	1979	1980	1981 - 1985
FY 1975 GO AHEAD	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D
LEADER - DELIVERIES	45	5	10	10	10	10
FAT						
PVT-C						
PVT-G						
OT-111						
FY 1977 GO AHEAD						
LEADER - DELIVERIES	20					
FY 1977 GO AHEAD						
LEADER - DELIVERIES (259)	309					
FOLLOW - DELIVERIES (50)						
FAT						
IPT						
FY 1978 GO AHEAD						
LOW BID DELIVERIES (570)	950					
HIGH BID DELIVERIES (380)						
FY 1979 GO AHEAD						
LOW BID DELIVERIES (570)	950					
HIGH BID DELIVERIES (380)						
FY 1980 GO AHEAD						
WINNER DELIVERIES (5452)	5452					
PRODUCTION TANKS						
KITS	1902					
TRAINING, FAT, ETC	5808					
TOTAL 7726	16					
GO AHEAD FY						
LEADER - DELIVERIES	324					
FOLLOWER	53					
LOW	1140					
HIGH	750					
WINNER	5452					
TOTAL 7726						

## APPENDIX C

## PLAN 3

**M60A1 P1 LASER/COMPUTER PRODUCTION**

REV 4-22-76

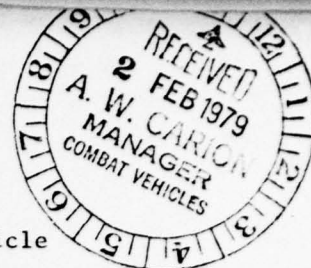




A.W. Carmon

APPENDIX D

FACT SHEET



Subject: Field Modification - M60A1 Vehicle to M60A1E3 Vehicle

Reference Material: (1) AR 750-1; "Army Materiel Maintenance Concepts and Policies - Chapter 3 Alteration of Materiel"  
(2) FM29-24; "General Support Maintenance Battalion"

Modification Work Order Considerations

The proposed modification would meet the criterion: "Increase significantly combat or operational effectiveness". This criterion for a Modification Work Order (MWO) carries the "NORMAL" classification. NORMAL modifications must be accomplished not later than twelve (12) months from the time compliance date. For field application below depot, General Support (GS) Maintenance would be the only type organization authorized for the proposed modification of M60A1 vehicle to a M60A1E3 vehicle.

The approved MWO must include as a minimum:

1. Remove turret from hull.
2. Remove existing components, tubing, electrical cabling, and most mounting brackets from turret.
3. Remove 2A engine, transmission, ancillary equipment, electrical cabling and mounting brackets from hull.
4. Overhaul/refurbish hull systems/components to be reused; e.g. suspension, controls (steering, braking, acceleration).
5. Overhaul/refurbish turret components that are to be reused.
6. Re-machine hull and turret ballistic armor to accept new and re-designed components/systems.
7. Re-weld hull and turret new design and/or relocated mounting brackets.
8. Install new turret components, tubing and wiring.
9. Install 2C engine (incl. oil cooled alternator and solid state regulator), transmission, new track, and other ancillary equipment in hull.
10. Marry turret to hull.
11. Perform vehicle checkout and final testing.
12. Perform vehicle road and boresight retention tests.

Additional MWO's would be required to rework/modify all components to be reused but requiring changes; e.g., hydraulic powerpack, gunners handles, periscopes. The only way to eliminate these MWO's would be to provide all new components already modified as kits.

The General Support (GS) Maintenance scope of work and costs must also include the following:

1. Application of mod kits to vehicle including manpower, tools fixtures, facility enlargement/changes.
2. Tools, Test Measurement and Diagnostic Equipment (TMDE's)
3. Inventory losses due to obsoleted parts.
4. Storage, transportation, training and other applicable services.

### General Support (GS) Maintenance Operation

For a field modification of this type, the G.S. Maintenance Battalion is the only maintenance level that could be considered for authorization to proceed with an approved MWO. Although a typical G.S. Maintenance Battalion (per FM 29-24) should have personnel with the necessary skills and facilities to at least perform fabrication and most assembly, the number of skilled personnel and the size of the facilities are not adequate. If a significant number of tanks are to be modified (including overhaul/refurbishment) in the twelve (12) month time period at each G.S. Operation selected, the significant problem areas below are evident:

- A. Possible problems associated with a typical G.S. Operation in regard to personnel are:
  - 1. Skills are present for fabrication and most assembly operations but some assembly operations (e.g. LRF installation) have special techniques that require special training.
  - 2. Test and checkout personnel would require extensive training for checkout of new components and systems unlike items presently in the domain of a typical G.S. operation - e.g., fire control, Laser Rangefinder and at some locations the add on stabilization system.
  - 3. Because of the increased workload G.S. must receive authorization and obtain additional skilled help in the form of civilian hires or contract personnel, then provide the necessary orientation and training. In foreign countries, language and metric vs. English measurement systems are additional problems.
  - 4. Production specialists not normally present at G.S. are required for: scheduling, costing, tool engineering, production control, manufacturing engineering and quality assurance personnel with production experience.
- B. A typical G.S. Maintenance facility has the capability to set up production lines for component modification and refurbishment but is not equipped to handle a tank production line for modification and refurbishment (usually performed at Depot). The possible problems associated with developing this capability are:
  - 1. Obtaining additional floor space for work areas, storage and office space.
  - 2. Obtaining additional general tools, furniture and storage racks.
  - 3. Obtaining special fixtures for machining and assembly.
  - 4. Obtaining production type inspection and checkout equipment.
  - 5. Maybe required to obtain such items of high dollar equipment as additional electrical power sources, overhead cranes and lift trucks.

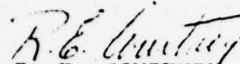


Conclusion

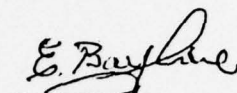
It is concluded that the modification or more correctly the modifications are too extensive and too time consuming to be accomplished by a typical G.S. Maintenance Operation along with its normal workload.

Recommend that this modification be accomplished at Depot.

Prepared by:

  
R. E. COURTNEY

Concurrence:

  
E. P. BAYLINE  
Maintenance Engrg. Supv.

## APPENDIX E

### Economic Analysis of AAD Versus MAD Conversion

#### Conversion:

<u>Time</u>	<u>Requirements</u>	<u>Location</u>
$t_1 = 1981$	264 M60A1 RISE	USAREUR
$t_2 = 1982$	490 M60A1 RISE	USAREUR
$t_3 = 1983$	490 M60A1 RISE	USAREUR
$t_4 = 1984$	490 M60A1 RISE	USAREUR
$t_5 = 1985$	490 M60A1 RISE	USAREUR

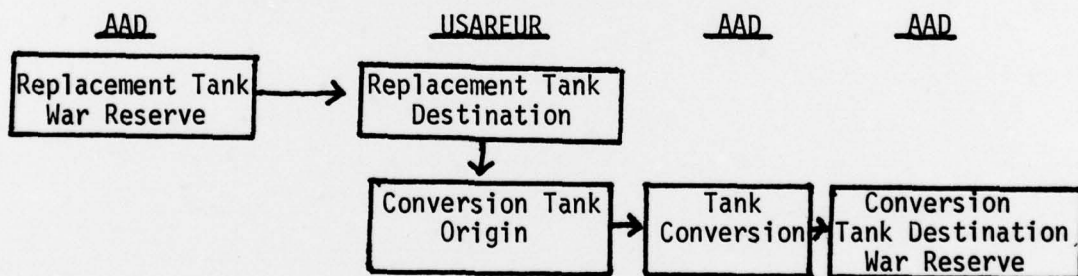
#### Conversion Alternatives and Locations:

Alternative 1 (AAD [Anniston Army Depot] -- CONUS)

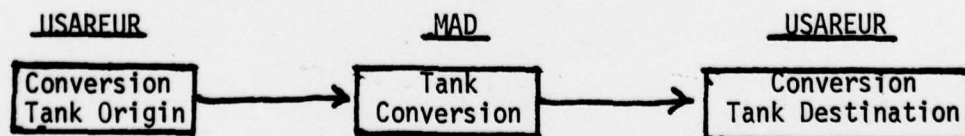
Alternative 2 (MAD [Maintz Army Depot] -- USAREUR)

#### Conversion Networks:

##### Alternative 1 (Conversion at AAD)



##### Alternative 2 (Conversion at MAD)



In alternative 1, the costs include: shipment of a tank from war reserve at AAD to USAREUR, referred to as  $T_{AU}$ ; shipment costs for a tank to be converted from USAREUR to AAD, referred to as  $T_{UA}$ ; and the variable cost for accelerating conversion capacity from 972 to 1,090 per year, referred to as  $VC_{(1090)}$ .

The formula for computing the cost for alternative 1 follows:

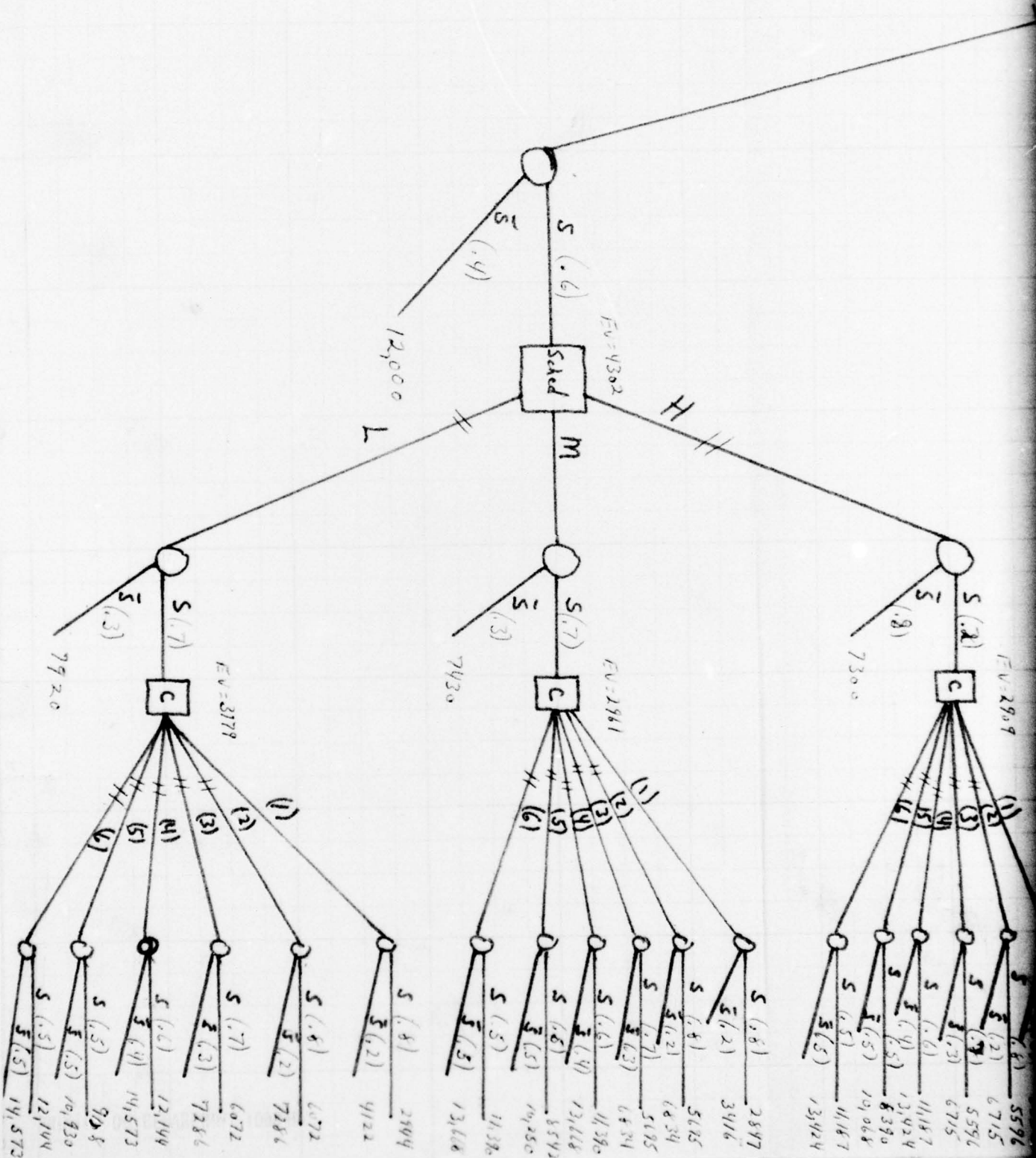
$$\text{Alt 1 Costs} = 2,226 (T_{AU}) + 2,226 (T_{UA}) + VC_{(1090)}$$

In alternative 2, the costs include: fixed costs to initiate operations at MAD,  $(FC_M)$ ; variable costs associated with yearly rates of 1,090 per year,  $(VC_{1090})_M$ ; and transportation costs for shipment of the product improvements to USAREUR,  $T_{(PI)}$ .

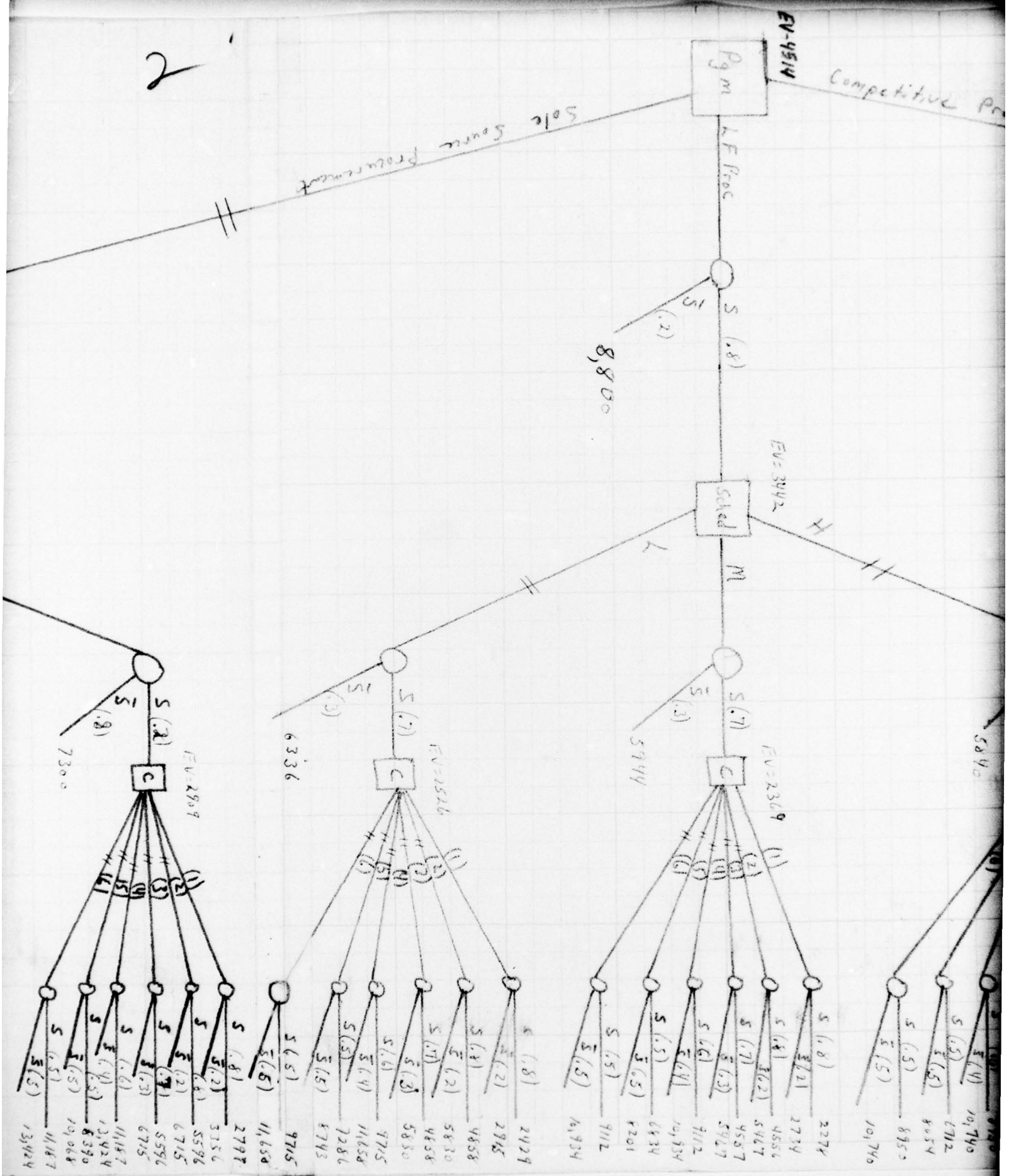
The formula for computing the cost for alternative 2 follows:

$$\text{Alt 2 Costs} = (FC + VC_{1090})_M + 2,226 T_{(PI)}$$

Transportation costs for both the product improvements and the tanks are calculated from port of origin, CONUS, to port of debarkation, USAREUR, because internal CONUS and USAREUR transportation charges would be similar for both alternatives and are therefore constants in the evaluations.





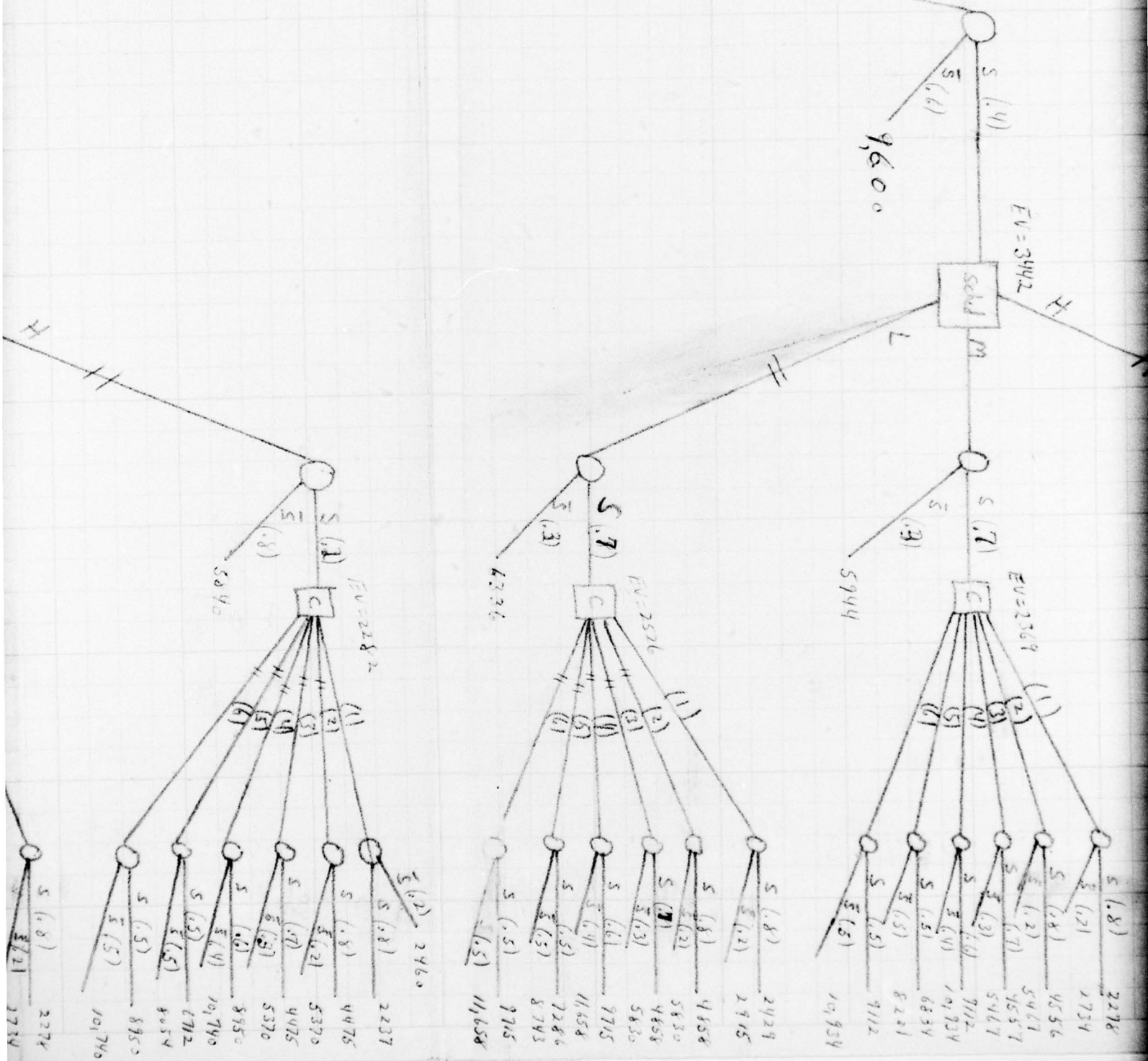


# APPENDIX F

## DECISION TREE--M60A1 CONVERSION

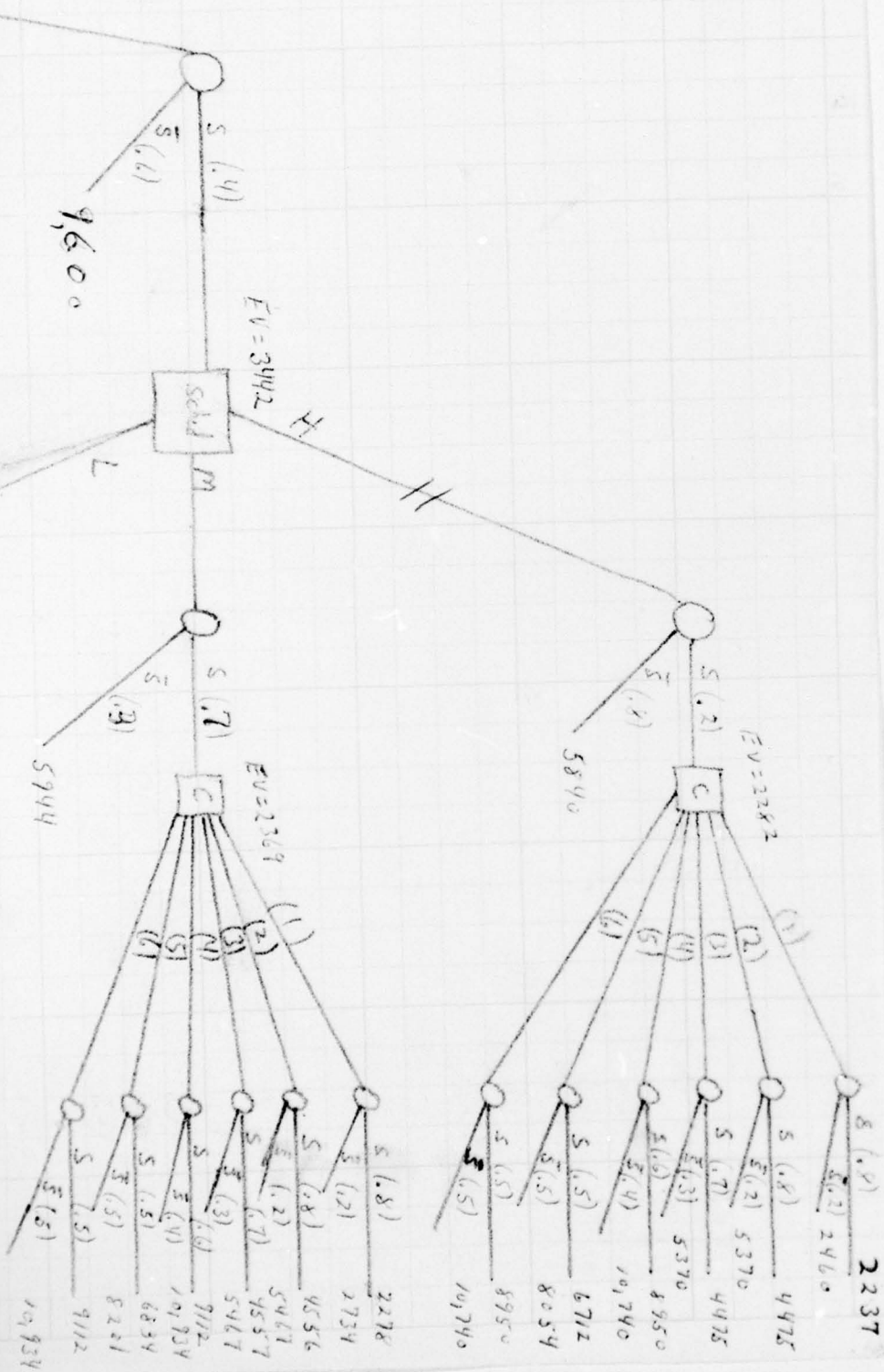
Competitive Procurement

3



# DECISION TREE - M60A1 CONVERSION PROGRAM

4





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LTC Flemming handles tank program requirements generation for the Army.
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Major Miller is the Executive Officer for PM-M60TD.
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LTC Myers is the M60A1 tank sponsor for US Army and is responsible for all M60A1 tank programs.
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Mr. Powers is responsible for tank overhaul and conversion programs at the national maintenance point for TACOM.
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